ENHANCING THE UNDERSTANDING OF BIOLOGY STUDENTS ON 'HOW' AND 'WHY' BIOLOGICAL PHENOMENA OCCUR THROUGH CAUSAL REASONING

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Abstract
Cause and effect of biological phenomena seem to remain ambiguous to most people, including biology students. Understanding the concept of biological phenomena requires proper articulation of biological concepts and scientific reasoning. This study on enhancing the understanding of biology students on how and why biological phenomena occur through causal reasoning was carried out in Enugu North local government area of Enugu State, Nigeria. The population of the study was 4,612 biology students in Enugu North local government area. The sample size was thirty (30) biology students. This was made up of one (1) male and one (1) female, biology student that were sampled through simple random sampling, by balloting, from each of the three senior secondary school classes of five public co-education schools in Enugu North local government areas. Pre-teaching and post-teaching of causal reasoning interviews were conducted on the students to determine the impact of teaching causal reasoning to the students. Data collected from their interview responses prior to the teaching and after the teaching of causal reasoning about biological phenomena were analyzed using Statistical Package for the Social Sciences (SPSS) and subjected to Chi-Square test at 0.05 level of significance, to determine the impact of the teaching on their understanding of how and why biological phenomena occur. The Chi-Square test result indicated that there was a significant association between causal reasoning with enhancement of the understanding of biology students on how and why biological phenomena occur. It was, therefore, recommended that teaching towards understanding how and why biological phenomena occurred, should be approached through scientific reasoning, by the teachers. Biology teachers should teach their students on how to think analytically and scientifically in order to understand and interpret biological phenomena.

Keywords: Causal reasoning, Biological phenomena and students.

Introduction

Considerable research exists on the development of causal reasoning in natural area including biology. Causal reasoning involves an interpretation of current events and explanation of past events. It involves identification of the cause-and-effect relationships that underpin biological phenomena. According to Legare (2008), a fundamental task for all humans is explaining 'how' and 'why' things happen. Causality according to

Goodman, Tomer and Joshua (2011) governs the relation between events. One particular skill that causal reasoning strengthens is critical thinking. As students develop the ability to identify causative factors in biology, they also learn to analyze and evaluate different biological phenomena. Animals and plants possess special features or structures that enable them adapt to their environments. There are basically three types of adaptations based on how the genetic changes are expressed. These are structural, physiological and behavioral adaptations. Structural adaptations are physical features of an organism's body that helps it to survive or reproduce within the environment. Unlike structural adaptation, physiological adaptation is internally based body chemistry and metabolism that enables the organism to survive in a changing environment. Behavioral adaptation on the other hand, is an organism's behavioral change in the face of a prey, predator, during mating/reproduction and changes weather condition. Structural, physiological and behavioral adaptations in plants and animals have shown some attendant causes and effects. Causes and effects of these biological phenomena seem to remain ambiguous to biology students (Mbajiorgu, Ezechi and Idoko, 2007). Understanding the concepts of biological phenomena requires proper articulation of biological concepts and scientific reasoning.

Malle, Moses and Baldioun, (2001), indicated that causal reasoning involves an interpretation of teleological or goal directed phenomena, the predication of future events and explanation of past events. According to Anidu, Eze and Mbajiorgu (2022), causal reasoning is the process of thinking about cause and effect from human minds tendency to provide causal explanations to the question of 'Why', 'How and 'What'. Gopnik (2001), has indicated that development of causal reasoning is particularly important in science learning as scientific invention such as hypothesis, theories and laws specifying causal relations among entities, events and processes. In Eze (2022), it was stated that causal reasoning is cause and effect related reasoning. Its purpose is basically to resolve the question of how and why phenomenon occurs. Proper knowledge structure and scientific conceptions are very necessary for biology student in resolving these questions on how and why a phenomenon occurred. Resolving these questions of how and why a phenomenon occurred involves mental process using causal reasoning. According to Mayr (2010), the idea of causal reasoning is to interpret what is seen as purposeful or goal seeking and predict how that behavior affects or effects what happens next.

To enhance the understanding of biology students on how and why biological phenomena occur through causal reasoning can be approached through any and or all of the following strategies:

Use of Real-Life Examples

This can be achieved by incorporating real-life examples and case studies to help students understand the cause-and-effect relationships in biological phenomena;

Encouraging Critical Thinking

This can be achieved by encouraging students to think critically about the biological process they are learning about. Charging them to analyze the factors that contribute to a particular outcome of different phenomena;

Interactive Activities

This can be achieved by engaging students in hand-on activities, experiments and simulations that will allow them to observe and understand the causal relationships in biological events;

Concept Mapping

This approach is by visually representing the causal relationships between different biological phenomena. It can help students see the interconnectedness of various processes and understand the underlying reasons for their occurrence.

Implementation of the above mentioned strategies can help biology students develop a deeper understanding of how and why biological phenomena occur, through causal reasoning.

Nevertheless, Bollocks, Gelman and Baillargon in Szymanowski (2008), identified three factors that could affect the interpretation, prediction and explanation of causal events in adults. These factors are;

1. the principles underlying definitions of cause and effects
2. the stimulus information utilized in making causal attributions and
3. The role of knowledge about objects in causal attribution and explanations.

The finding of the study would be anchored on theory of constructivism. Constructivism according to WNET (2004), is basically a theory – based on observation and scientific study about how people learned. It is a philosophical viewpoint about the nature of familiarity, awareness or understanding of someone or something, such as facts, information, descriptions or skill, which is acquired through experience or education by perceiving, discovering or learning. It is founded on the premise that, by reflecting on our experiences, we construct our own understanding of the world we live in.

Tamir and Zohar (1991) in Southerland and Hayne (2001) developed seven categories of reasoning that could enable biology students proffer answers to how and why biological phenomena occur.

These were:

Anthropomorphic: This attributes human as the causal agent for changes seen in non-human organisms. It also includes an explanation in which the organisms (human and non-human) is seen as been able to manipulated or effect the change willfully.

Teleology: This attributes the end as the agent of determining the nature of the phenomenon. It involves the identification of the inherent purpose, intent or end of a phenomenon.

Mechanistic Proximate: This attributes a specific physiological or biological agent to determining the nature of the phenomenon. Typically, such an explanation describes the actions of just the individual and does not consider the entire group or population of organisms.

Mechanistic Ultimate: This attributes a long term, generally, genetically based agent to determining the nature of the phenomenon.

Such explanation describes the entire characteristic of population of an organism and not just the actions of and individual.

Predetermined: This is where the agent is not clearly identified, thus the nature of the phenomenon is attributed to God or nature.

Blended: This reasoning combines the attributes of more than one of the category of reasoning to explain a phenomenon.

Don't know: This is a situation where the respondent does not know what to say or what to attribute the phenomenon to.

Statement of the Problem

Understanding and explanation of how and why biological phenomena occur have remained a big challenge to most biology students, including their teachers. The question, therefore is, can the understanding of biology students on how and why biological phenomena occur be enhanced through causal reasoning?

The purpose of the study was to determine if causal reasoning could enhance the understanding of biology students on how and why biological phenomenon occurs. Two research questions and two hypotheses were posed for the study.

Research Question 1

What is the association of causal reasoning with enhancement of the understanding of biology students on how biological phenomenon occurs?

Research Question 2

What is the association of causal reasoning with enhancement of the understanding of biology students on why biological phenomenon occurs?

Hypothesis 1

There is no significant association between causal reasoning with enhancement of the understanding of biology students on how biological phenomenon occurs.

Hypothesis 2
There is no significant association between causal reasoning with enhancement of the understanding of biology students on why biological phenomenon occurs.

Method

Survey research design was adopted for study. The population of study was 4,612 biology students from five (5) public co-education secondary schools in Enugu North local government area of Enugu state. Simple random sampling by balloting was used to sample one (1) male and one (1) female each of the three classes of senior secondary biology students giving a total of six (6) students from each school. Thus a total sample size of 30 students responded to interview. The instrument for data collection was an open-ended structured interview schedule (SIS) that was developed based on one animal specimen and one plant specimen that were used for the study. These were colored pictures of a chameleon (with changing color) and Nepenthes (with tongues). The interviews were designed for collection of data on the students' causal reasoning and their causal explanation on some identified biological phenomenon found in the animal and the plant. This was done to identify their choice of category of reasoning from the seven categories of reasoning as identified Tamir and Zohar in Southerland et al (2001). In order to identify their choices of categories of reasoning they were interviewed on how and why some identified biological phenomena occur in the chosen specimen (chameleon and Nepenthes). Pre-teaching of causal reasoning interview and post teaching of causal reasoning interview were conducted on the students.

The instrument was sent to three experts in the relate fields of the study for face validations. It was examined based on content area, appropriateness and clarity of the interview items to ascertain the extent to which the instrument could measure what it was meant to measure. The instrument was not subjected to reliability test as it was for soliciting open-ended responses.

1. Structured interviewed schedule (for chameleon)
    a. How did chameleon get behavioral coloration changes?
    b. Why did the chameleon have the behavioral coloration changes?

2 Structured interview schedule (for Nepenthes)
    a. How did the Nepenthes get its tongue?
    b. Why did the Nepenthes have tongues?

Data collected from pre-teaching interview and post-teaching interview was analyzed electronically using Statistical Package for the Social Sciences (SPSS) and tested with Chi-Square at 0.05 significant levels. The null hypothesis would be rejected if the Chi-Square test result was equal or greater than critical value at the appropriate degree of freedom, and would not be rejected if Chi-Square test was less than the critical value.

Results

Research Question 1

What is the association of causal reasoning with enhancement of the understanding of biology students on how biological phenomena occur?

Cross tabulation of pre-teaching and post-teaching of causal reasoning interview responses given by biology students with categories of reasoning, on how biological phenomena occur.

How Categories of Reasoning	Pre-teaching responses Count	%	Post-teaching responses Count	%	Total Count	%
Anthropomorphic	0	0	0	0	0	0
Teleology	3	5	26	43.33	29	24.17
Mechanistic Proximate	8	13.33	6	10	14	11.67
Mechanistic Ultimate	18	30	20	33.33	38	31.67
Predetermined	25	41.67	4	6.67	29	24.16
Blended	6	10	4	6.67	10	8.33
Don't know	0	0		0	0	0
Total	60	100	60	100	120	100

The above table revealed that the students' choice of responses with scientific categories of reasoning were more after post-teaching of causal reasoning as against their pre-teaching of causal reasoning choice or responses. Their choice of mechanistic ultimate and teleology categories increased after teaching them causal reasoning, while their choice of non scientific categories of reasoning, like predetermined and blended, on how biological phenomena occur reduced.

Research Question 2

What is the association of causal reasoning with enhancement of the understanding of biology students on why biological phenomena occur?

Cross tabulation of pre-teaching and post-teaching of causal reasoning interview responses given by biology students with categories of reasoning, on why biological phenomena occur.

Why Categories of Reasoning	Pre-teaching responses Count	%	Post-teaching responses Count	%	Total Count	%
Anthropomorphic	0	0	0	0	0	0
Teleology	4	6.67	28	46.67	32	26.67
Mechanistic Proximate	7	11.67	4	6.67	11	9.17
Mechanistic Ultimate	16	26.66	23	38.33	39	32.5
Predetermined	26	43.33	3	5	29	24.16
Blended	7	11.67	2	3.33	9	7.5
Don't know	0	0	0	0	0	0
Total	60	100	60	100	120	100

The above table revealed that the students' choice of responses with scientific categories of reasoning were more after post-teaching of causal reasoning as against their pre-teaching of causal reasoning choice or responses. Their choice of mechanistic ultimate and teleology categories increased after teaching them causal reasoning, while their choice of non scientific categories of reasoning, like predetermined and blended, on why biological phenomena occur reduced.

Hypothesis 1

There is no significant association between causal reasoning with enhancement of the understanding of biology students on how biological phenomena occur.

Chi-square test result for how biological phenomena occur

Description	Value	df		Sig(2sided)
Pearson Chi-Square	13.61	32	6	0.00
Number of Valid Cases	120			

Critical value $\chi^2_{0.05}=12.592$

Chi-square test result=13.6132

In line with the decision rule, the null hypothesis was rejected as the Chi-square test result was greater than the critical value at 6 degree of freedom. Hence, the alternative hypothesis which states that there is significant association between causal reasoning with enhancement of the understanding of biology students on how biological phenomena occur is accepted.

Hypothesis 2

There is no significant association between causal reasoning with enhancement of the understanding of biology students on why biological phenomena occur.

Chi-square test result for why biological phenomena occur

Description	Value	df		Sig(2sided)
Pearson Chi-Square	13.98	36	6	0.00
Number of Valid Cases	120			

Critical value $\chi^2_{0.05}=12.592$

Chi-square test result=13.9836

In line with the decision rule, the null hypothesis was rejected as the Chi-square test result was greater than the critical value at 6 degree of freedom. Hence, the alternative hypothesis which states that there is significant association between causal reasoning with enhancement of the understanding of biology students on why biological phenomena occur is accepted.

Findings

Prior to teaching of causal reasoning the biological students were using non scientific reasoning in explaining how and why biological phenomena occur. Their choices of categories of reasoning inclined more to the use of predetermined category of reasoning, which was a non scientific way of reasoning. On the contrary, after the teaching of causal reasoning the biology student choice of reasoning changed to scientific ways of reasoning by inclining more the use of mechanistic ultimate and teleology reasoning categories as their choice of reasoning to understand how and why biological phenomena occur. Mechanistic ultimate and teleology categories of reasoning implore systematic observations, recording of occurrences and interpretation of occurrences before making conclusive statements.

Discussions of the Findings

The chi-square test result indicated that the association of causal reasoning with enhancement of understanding of biology students on how and why biological phenomena occur was significant. The choice of use of mechanistic ultimate and teleology categories of reasoning increased after teaching the students, causal reasoning. This implies that many of the biology students relinquished their presuppositions on biological phenomena and became more analytical of the causal agency through constructive reasoning. Progressive psychologists explore the growth and expansion of reasoning from birth to maturity. According to Demetrions, Monyi & Spanoudis (2010) changes in reasoning with development come from increasing work, education, and memory capacity, increase speed of processing, enhanced executive functions and control, including self awareness. It would be appropriate to expect difference in students' causal reasoning as they receive and acquire more scientific education. This might be the reason why the chi-square test result indicated that there was significant association between causal reasoning with the enhancement of these biology students' understanding of how and why biological phenomena occur.

Conclusion

Enhancing the understanding of biology students on how and why biological phenomena occur through causal reasoning, has been identified as a veritable tool for biology students' understanding and explaining cause-and-effect of biological phenomena. Understanding and explanation of cause-and-effect of biological phenomena have remained big challenge to secondary school biology students and in most cases impact negatively on their academic performances. The major reason for the poor performance of biology students in explanation of biological phenomena is their lack of ability to reason in scientific ways. Causal reasoning is a scientific approach to teaching and understanding how and why biological phenomena occur. It implores some strategies to instill knowledge and understanding of biological phenomena on biology students. The seven categories of reasoning by Tamir and Zohar (1991), is one of the strategies in use.

This particular strategy presents seven different ways of viewing any biological phenomena as to understand how and why it occurred. The results of both hypotheses posed in this work have shown that the biology students that passed through causal reasoning tutelage performed better in understanding how and why biological phenomena occurred. Teaching and learning of biology that is based on causal reasoning most often, enhance biology students' understanding of biology and biological phenomena.

Recommendations

Based on the finding of the study, it was recommended that teaching towards understanding how and why biological phenomena occur should be approach through scientific reasoning. Students should be taught on how to think analytically and scientifically using different causal reasoning strategies, in order to understand the phenomena. In most case, cause-and-effect of any phenomenon transcend what the normal eye could see, how and why it happen, the nature and intent of the phenomenon need to be understood. This can only be achieved through causal reasoning, which has to do with analyzing current event and predicting the future effect of such event.

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